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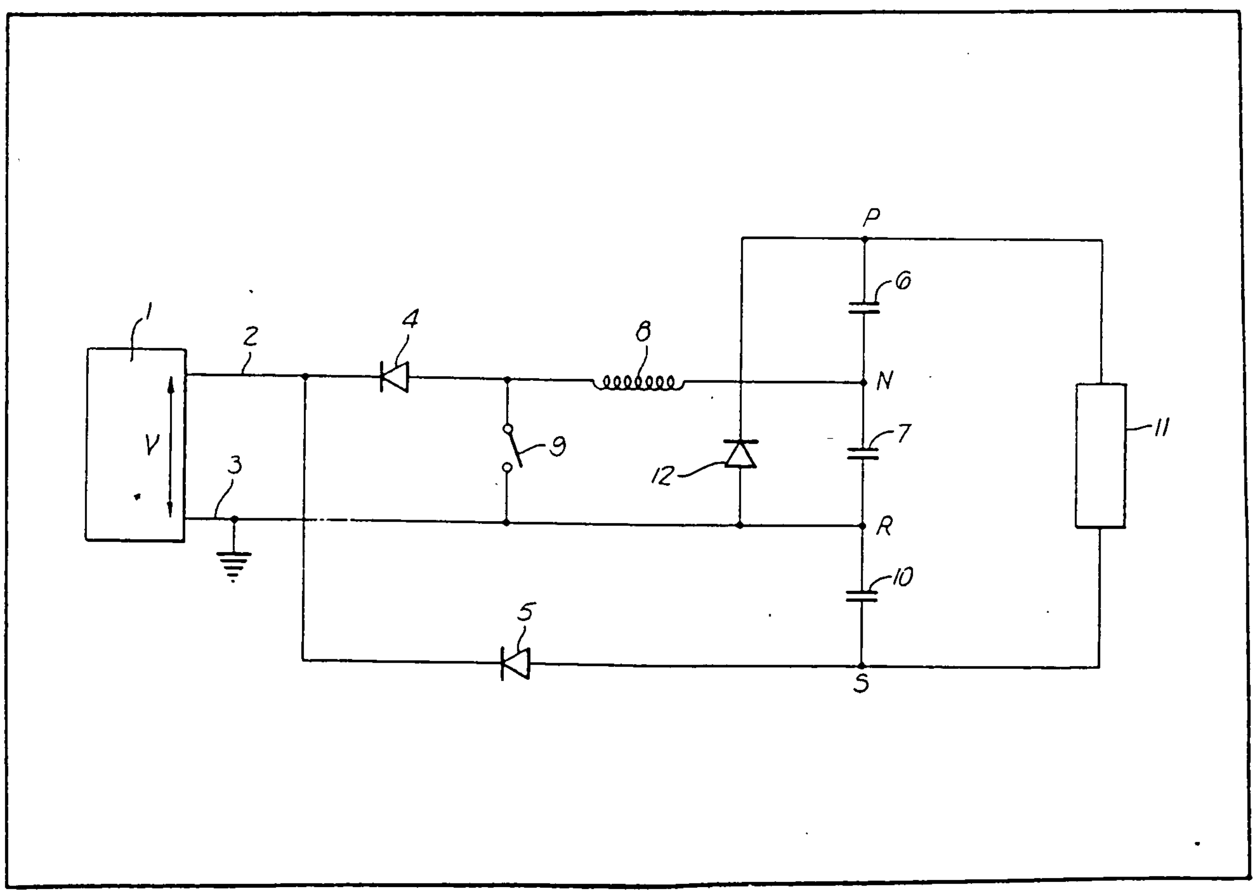
(71) Applicant
British Aerospace plc,
(Great Britain),
100 Pall Mall,
London,
SW1Y 5HR
(72) Inventor
John Robert Baron
(74) Agents
British Aerospace plc,
E. C. Dowler,
Corporate Patents Dept,
Brooklands Road,
Weybridge,
Surrey,
KT13 0SJ

(54) Voltage multiplying power supply

(57) The power supply is intended particularly for supplying high voltage gas laser pump pulses and comprises a Blumlein type voltage doubler and an extra capacitor (10) connected to the voltage doubler so as to give a voltage-trebling effect.



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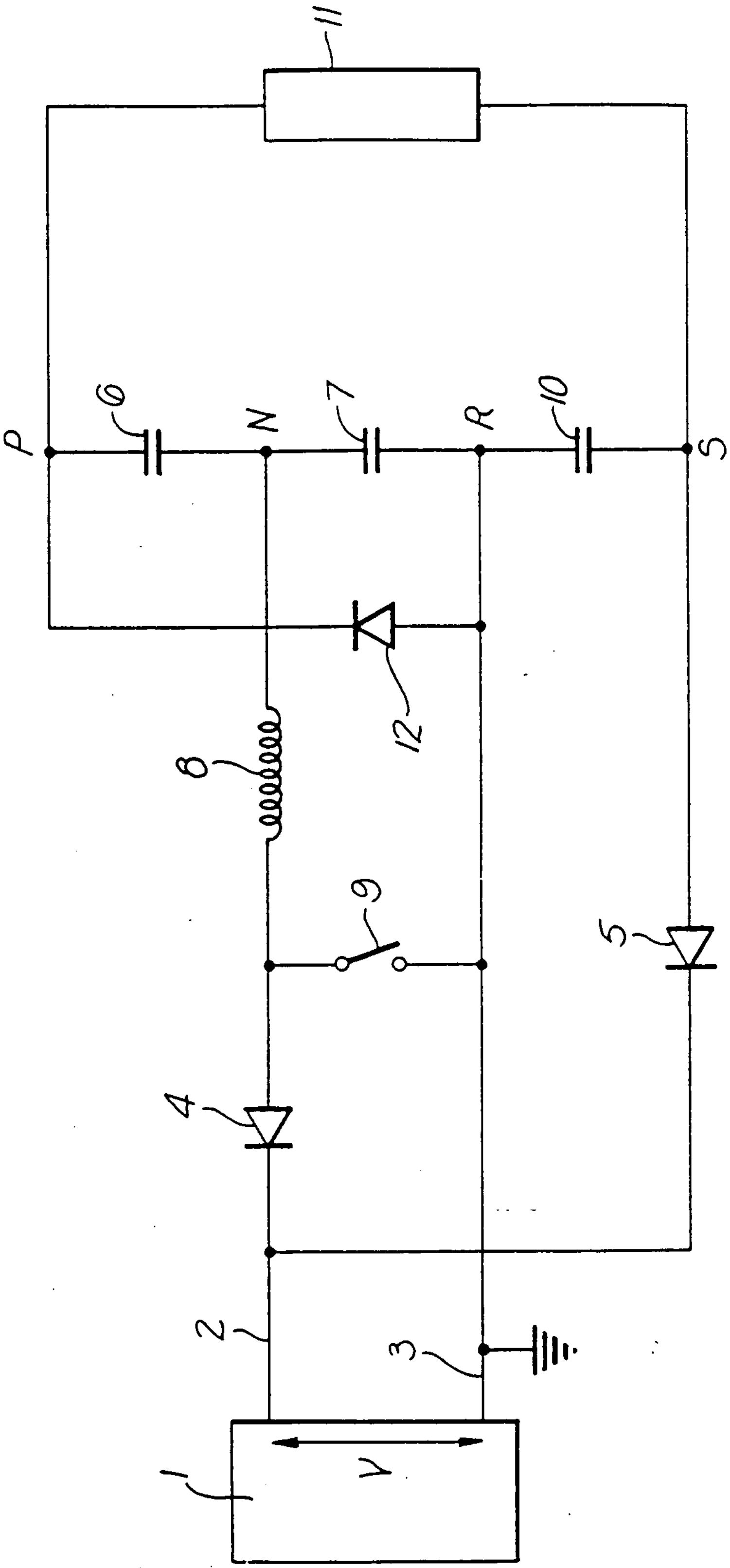
11
P
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V

SPECIFICATION
Power supplies

This invention relates to power supplies, more particularly but not exclusively to high-voltage pulse power supplies for pumping gas-discharge lasers.

It is known to pump such lasers by relatively slowly charging a capacitor from a d.c. source *via* a resistor and then rapidly discharging the capacitor into the laser *via* a switch. An improvement can be effected by use of a Blumlein voltage doubler wherein two capacitors are charged *via* an inductor, the first capacitor and the inductor forming a tuned circuit and a switch being connected across this tuned circuit, and the second capacitor leading to the laser. Depending on the laser, means may be needed to ensure a charging path for the second capacitor, for example an inductor parallel to the laser. After charging, the switch is closed so the charge on the first capacitor reverses. Meanwhile, the second capacitor remains charged, so the voltage applied to the laser goes to a value which, in a theoretical ideal case, would be twice the source voltage but which, because of losses mainly due to inevitable limits on the attainable Q of the tuned circuit, will be somewhat less than this, perhaps 1.7 times the source voltage.

According to the present invention, there is provided a power supply circuit including energy supply means, and a voltage-multiplier section having two capacitors connected for being charged by said supply means and reversing means for causing the charge on one of the capacitors to be reversed whereby the sum of the voltages across the respective capacitors becomes available, the power supply circuit including a further capacitor connected to said energy supply means to be charged thereby and to said voltage multiplier section to make available a voltage equal to said sum plus the voltage across the further capacitor.

The voltage multiplier section may comprise an inductor connected between said supply means and said two capacitors to pass charging current thereto, one of the capacitors forming a tuned circuit with the inductor, and a switch for discharging said one capacitor through the inductor and thereby causing the charge on the one capacitor to be reversed.

Advantageously, the energy supply means comprises a transformer with a core and means for building-up current in the primary winding of the transformer and hence energy stored in its core and then causing that stored energy to appear as a high-voltage pulse at the secondary winding terminals of the transformer.

For a better understanding of the invention, reference will now be made, by way of example, to the accompanying drawing, the single figure of which is a partly simplified diagram of a power supply circuit and a gas discharge laser arranged to be pumped by the power supply circuit.

The illustrated power supply circuit comprises an energy source 1 having output terminals 2 and 3 between which a drive voltage V is formed. Terminal 3 is grounded while terminal 2 is connected to the respective cathodes of two diodes 4 and 5. The power supply circuit includes a voltage-doubler section having two capacitors 6 and 7 connected in series with their point of interconnection N coupled *via* an inductor 8 to one side of a switch 9 and to the anode of diode 4. Capacitor 7 and inductor 8 form a tuned circuit.

A further capacitor 10 is connected to capacitor 7 to form a series chain of the three capacitors, the chain being connected in parallel with the discharge path of a gas discharge laser 11, of which laser the threshold voltage for initiation of discharge therethrough is greater than V. One end of the series chain, *i.e.* the point of interconnection P between capacitor 6 and laser 11, is connected to the cathode of a diode 12, the anode of this diode being connected to the other side of switch 9, to source terminal 3, and to the point of interconnection R between capacitors 7 and 10. The other end of the chain, *i.e.* the point of interconnection S between capacitor 10 and laser 11 is connected to the anode of diode 5.

The polarities of diodes 4, 5 and 12 may be reversed but, if they are as shown, the voltage at terminal 2 of source 1 is made negative with respect to ground.

Initially switch 9 is open. Capacitor 7 becomes charged *via* diode 4 and inductor 8, capacitor 6 is charged *via* diodes 4 and 12 and inductor 8, and capacitor 10 is charged *via* diode 5. Following charging, therefore, points P and R are at or near ground potential while points N and S are at a potential −V. Switch 9 is now closed so that capacitor 7 discharges *via* inductor 8. This capacitor and the inductor being tuned to one another, the potential at point N goes through zero and continues on up to a positive value which, ideally, would be +V but in practice, due to losses, might be around +0.7V. Meanwhile, due to the action of diode 12, capacitor 7 remains charged so the potential at point P rises to around +1.7V, *i.e.* zero plus the change in potential gone through at point N. Capacitor 10 also remains charged so the potential at point S stays at −V. Thus, the voltage now appearing across the laser 11 is 2.7V.

It will be appreciated that as compared with the basic Blumlein voltage-doubler, for a given output voltage, the required source voltage, the voltages appearing across the individual capacitors and hence the required capacitor ratings, and the risk of Corona generation are all somewhat less. Also, for the illustrated circuit the final output voltage is the sum of a portion 2V obtained by charging capacitors 6 and 10 through diodes 12 and 5 respectively, and a portion, say 0.7V, comprising the original charge on capacitor 7 less the losses due to reversal through inductor 8. The output of a simple Blumlein voltage double is made up of a portion V plus a portion, again 0.7V say, equal to V less the reversal losses. Thus,

for a given output voltage, the proportion of that output voltage which is subject to reversal losses is less for the illustrated circuit than for the Blumlein circuit and the efficiency of the illustrated circuit is correspondingly the higher.

The source 1 could be a d.c. voltage source but it preferably comprises a transformer, advantageously a step-up transformer, of which the primary is fed from a suitable supply and of which the secondary is connected to terminals 2 and 3 (not shown). Particularly advantageously, the transformer could form part of a source constructed according to principles disclosed in our patent application No. 8112210. For example, it could comprise a cored transformer of which the primary winding, or the primary part of the winding if it is an autotransformer, is fed with current by way of a switch, which switch is opened when the current and hence the energy stored in the transformer core have built-up to a required value so that this energy appears at the transformer secondary as a pulse.

Possibly in dependence particularly on the nature of source 1 and also the desired efficiency and effectiveness of the circuit, it may be possible to replace one or more of the diodes 4, 5 and 12 by alternative components, for example resistors, inductors or electronic switches of one or another kind.

The switch 9 could comprise a spark-gap or a Thyratron for example. If so, it may be able to be driven by energy stored in the primary winding of the aforementioned cored source transformer according to the principles disclosed in connection with drawing figure 3 of our patent application No. 8112210.

The grounding of terminal 3 of the source 1 as shown is preferred since then the terminal 2 is never at a higher potential than V with respect to ground and the insulation and such used to isolate terminal 2 from ground can be provided accordingly. This is particularly important when the source comprises a high-voltage transformer. It does mean, however, that neither side of the laser can be grounded unless this be by way of some special means which avoids shorting out of capacitor 10 on the one hand or capacitors 6 and 7 on the other. If it is required to ground one side of the laser, then this can be done provided that source terminal 3 is not, or provided that some special measure is taken as before.

When capacitor 10 has been charged, a voltage V is applied to the laser and this is why the laser has a discharge threshold greater than V. A gas-discharge laser may comprise a pre-ionisation arrangement for setting-up an initial discharge which preionises the gaps between the main discharge electrodes and thereby facilitates the main discharge. If the preionisation arrangement would be such as to prevent or seriously delay charging of capacitor 10, for example if it provides a current flow path of which the conductivity is too high or if it defines a preionisation discharge gap but the threshold for discharge thereacross is lower than V, then the laser should be chosen or adapted so that at least not both of the preionising arrangement supply terminals are common to the main discharge terminals. Then, the preionisation arrangement may be connected between points P and R in the drawing, and would hence receive no voltage until the switch 9 closes, while the main discharge path is supplied from points P and S.

The circuit shown could be incorporated into a larger circuit giving a further multiplication of the source voltage V. For example, a circuit could be made up of two circuits each similar to the one shown but possibly having some parts in common and arranged so that the output voltages thereof are summed to drive the laser. Also, one or more additional capacitors can be included in the chain, connected between point P and the laser for example. Then, the first such additional capacitor would be arranged like capacitor 7 for being discharged *via* an inductor so the charge there-across reverses, the next, if present, is connected to be charged like the capacitor 6 and so on.

As a further possible development of the illustrated circuit, using principles disclosed in our patent application No. 8122573, the inductor 8 may form the primary winding of a transformer (not shown) of which the secondary winding is connected in series between capacitor 6 and laser 11. The transformer windings may have the same number of turns and may in fact comprise a coil of coaxial cable, one conductor of which, preferably the screen, forms the primary while the other conductor forms the secondary. Providing the transformer windings have good coupling and no substantial core saturation takes place, an additional voltage component will be induced in the transformer secondary winding and become added to the final output voltage.

The power supply disclosed herein may be operable, as desired, to supply regularly repetitive pulses to the laser 11, or for single-shot and/or irregular repetition operation. The resonant frequency of the tuned circuit comprising capacitor 7 and inductor 8 may be made variable to allow adjustment of the delay between the closing of switch 9 and the application of the output voltage pulse to the laser.

Finally, it will be well appreciated that the load driven by the illustrated circuit need not be a gas discharge laser or even a laser at all. Rather, the circuit is usable for providing a voltage drive or pulsed voltage drive to various kinds of load which require it. Generally, such a circuit would be most appropriate for high voltage supplies but even that is not essential.

Claims

1. A power supply circuit including energy supply means, and a voltage-multiplier section having two capacitors connected for being charged by said supply means and reversing means for causing the charge on one of the capacitors to be reversed whereby the sum of the voltages across the respective capacitors

becomes available, the power supply circuit including a further capacitor connected to said energy supply means to be charged thereby and to said voltage-multiplier section to make available a voltage equal to said sum plus the voltage across the further capacitor.

2. A circuit according to claim 1, wherein the voltage multiplier section comprises an inductor connected between said supply means and said two capacitors to pass charging current thereto, one of the capacitors forming a tuned circuit with the inductor, and a switch for discharging said one capacitor through the inductor and thereby causing the charge on the one capacitor to be reversed.

3. A circuit according to claim 1, wherein the energy supply means comprises a transformer with a core and means for building-up current in the primary winding of the transformer and hence energy stored in its core and then causing that stored energy to appear as a high-voltage pulse at the secondary winding terminals of the transformer.

4. A power supply circuit substantially as hereinbefore described with reference to the accompanying drawing.

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